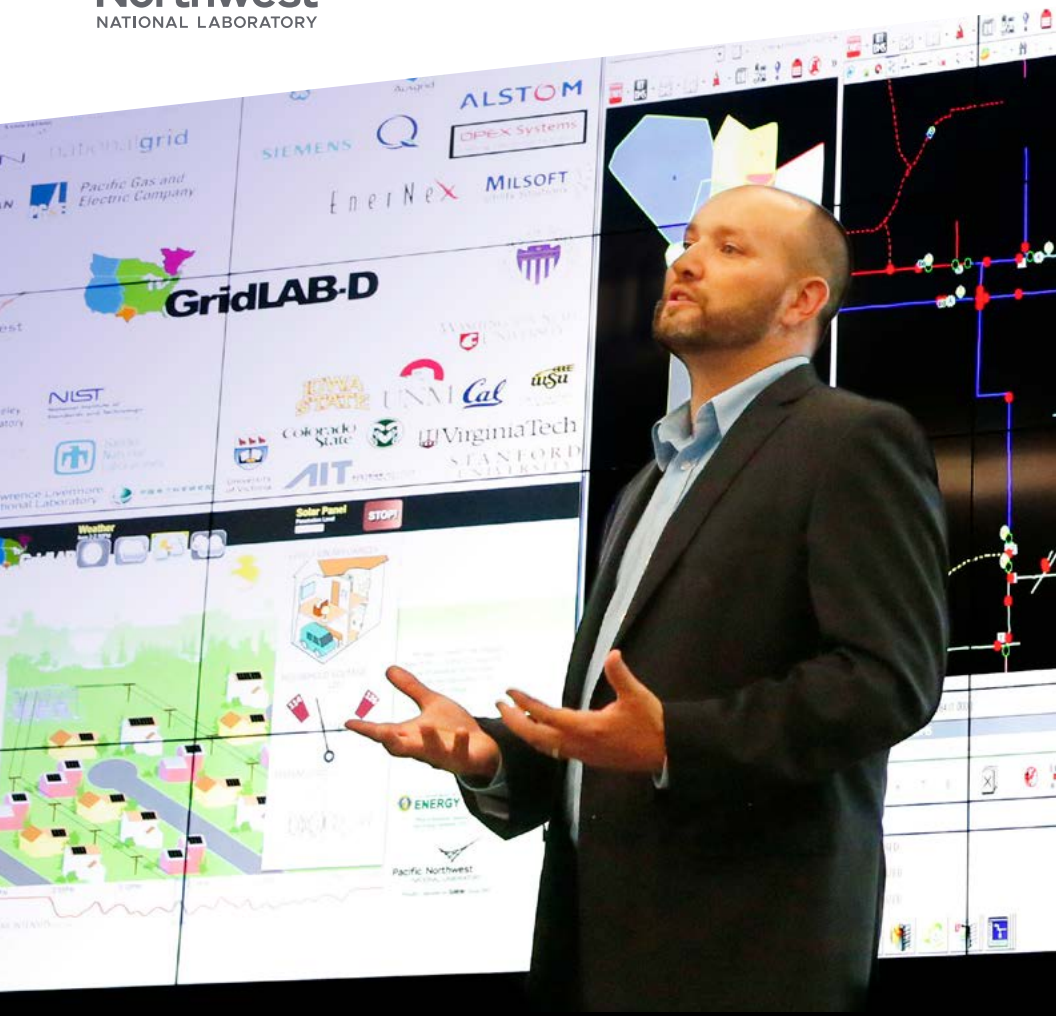
Pacific Northwest
NATIONAL LABORATORY



OPERATIONAL SOFTWARE

FOR GRID MODERNIZATION

By choosing the latest grid analytics software tools from Pacific Northwest National Laboratory, you can:

- Optimize grid operations and controls while reducing costs
- Inform decisions about distribution systems and grid energy storage
- Evaluate equipment health and infrastructure damage
- Improve utility products.

The tools described in this brochure were developed and tested with a variety of users, such as utilities, independent system operators, regulators, commercial vendors, and other grid stakeholders.

1 Energy Storage

2 Distribution

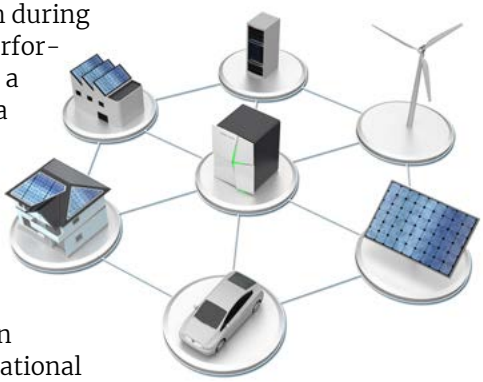
5 Transmission

6 Demand Response and Microgrids

ENERGY STORAGE

Non-Linear Battery Model | 30953

Reliably estimates a battery's charging state during operation



This software estimates the state-of-charge (SOC) in a battery energy storage system during operation, reflecting the actual performance of the system. Because it is a self-learning model that uses data directly from the battery itself, the estimate is more reliable than other, indirect methods. The estimate accounts for conditions such as operating mode, power, state of health, SOC range, and temperature. This information provides more flexibility and operational knowledge, which can improve the economic operation of the battery storage system. For example, to maximize revenue during market operations, the model can define optimal charging rates and find operational "sweet spots" that minimize energy losses.

Battery Storage Evaluation Tool | 30603

Evaluates the combined monetary benefits of batteries for specific uses

When considering various battery storage systems, utilities and vendors need to understand the financial benefits of particular battery types in specific locations. This comprehensive software tool can determine those values. It defines optimal control strategies and estimates revenue for a variety of use cases or possible grid applications, including ancillary services, energy arbitrage, balancing service, distribution system equipment deferral, and outage mitigation. It looks at the entire system, down to the local distribution level. The results show the monetary benefits of a particular battery, used for various services, in particular grid locations.

Grid Battery Storage Optimization Tool | 30651

Shows the optimal battery sizes, locations, and performance controls for a project

Once an energy storage project has been green-lighted, utilities and vendors need to determine the best size, placement, and operation of the battery. By combining engineering and economic assessments, this tool pinpoints the optimal sizes and performance control strategies for batteries used in various applications. The Grid Battery Storage Optimization Tool can evaluate both utility-owned and behind-the-meter energy storage while defining the optimal battery size for economic opportunity.

Optimal Controller for Hybrid Energy Storage | 16599

Coordinates the performance of energy resources

Energy providers are adding more and different kinds of energy storage and devices to their conventional generation resources. The patented hybrid energy storage controller, a combination of hardware and software intellectual property, coordinates and optimizes the way these resources work together. It controls the entire mix of resources, including energy storage devices, demand response programs, dynamic interchange schedules, and conventional regulating units. In addition, the controller maintains a desired state of battery charge, prevents energy balancing violations, and optimizes energy generation output.

DISTRIBUTION

GridLAB-D™ v. 4.0 | 31157

Evaluates options for power distribution systems

GridLAB-D™ simulates and analyzes electric power distribution systems over time, from seconds to decades. Users get a "test bed" for evaluating the feasibility and cost effectiveness of smart-grid technologies without costly trial-and-error field demonstrations. The software analyzes control strategies for physical assets, electricity markets and rate structures, and end-use loads down to the appliance level. Users in more than 170 countries have downloaded GridLAB-D™ more than 80,000 times since its open-source release in 2008. Version 4.0 features microgrid operations, communicates with hardware and external software, and controls distributed generation and smart inverters.

Remote Measurement of Transformer Loading/ Overload Conditions | 31304

Provides a simple way to calculate conditions during normal and emergency operations

This unique software calculates distribution transformer loading conditions. With readily available data, such as the transformer's full-load core-loss value, base load, and secondary voltage, the user can determine a no-load transformer voltage, which can verify that transformer voltage remains above its minimum voltage and determine the transformer's current loading to ensure safe and stable operation during typical and atypical conditions.

Bump Test and Evaluation for Volt/VAR Optimization Systems | 30640

Validates VVO systems in less time

Regulatory authorities require utilities to validate the effectiveness of their Volt/VAR Optimization (VVO) systems for peak and energy reductions. However, validation typically requires an expensive, two- to three-month on and off evaluation process. This new software enables accurate evaluation in just two weeks, saving time and money. Also, if integrated into VVO tools, it could show system performance not just when commissioned, but continually.

Microgrid Stabilization Using VVO | 31079

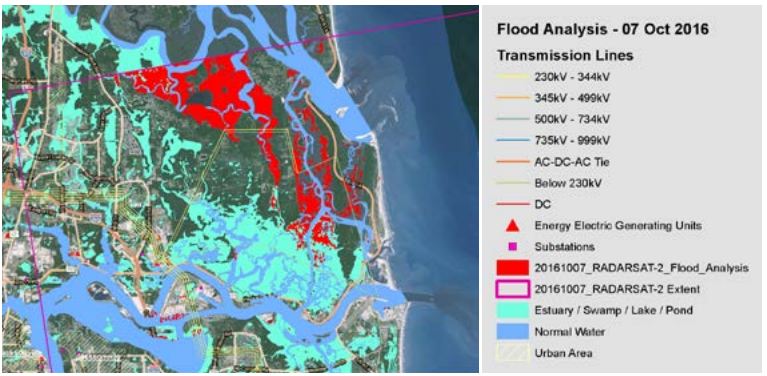
Stabilizes microgrids with no added equipment

Microgrids typically use oversized generation units to maintain stability, which can be costly. Instead, this patent-pending method uses existing voltage regulation equipment with a VVO approach to improve microgrid stability. With this approach, operators can adjust generators, voltage regulators, and reactive power sources in real time, increasing system stability without adding costly new equipment. In addition, microgrids can use smaller, less costly generators while operating at more efficient levels.

Automated Damage Assessment for Disaster Response | 30963

Shows damage in a utility's territory

When disaster strikes, utilities must respond quickly and efficiently. This software detects and displays areas damaged by extreme weather events using remote sensing imagery and meteorological data. The software looks for rubble, land-cover changes, and damage from tornados and ice storms. The results show areas of a utility's territory that may have been damaged by high winds, are flooded and inaccessible, or have damaged vegetation indicating downed lines from falling trees. The maps can be combined with the utility's own infrastructure information, such as locations of transmission lines and substations. The resulting images can be viewed in Google Earth or any other geospatial software.



With the PNNL Automated Damage Assessment tool, operators can see where electrical utility infrastructure may have been affected. This image shows flooding impacts in Jacksonville, Florida after Hurricane Matthew hit in 2016.

TRANSMISSION

HPC-Based Unit Commitment Solver | 31055, 31328

Reduces power planning time

Unit commitment and dispatch scheduling has traditionally been a long-term planning function. However, with the availability of high-performance computers (HPC), this analysis can be done much faster. PNNL's HPC-Based Unit Commitment Solver, known as HIPPO, can make unit commitment a more operational tool and give planners more time to consider new contingencies and variables. HIPPO's algorithms share information, produce more accurate results, and reduce computing time to a fraction of what current methods take.

ACE vs. BAAL Visualization Tool | 31101

Helps balancing authorities comply with new standards

Balancing authorities are coping with significant changes that affect operations, including the 2016 Balancing Authority Area Control Error (ACE) Limit (BAAL), as well as the rapid rise of variable generation, weather shifts, and market changes. All of these factors require a deeper understanding in shorter time periods. With this open-source software tool, balancing authorities can visualize the movements of ACE vs. the BAAL for each hour of the day. Operators can use the results to better control their ACE to ensure compliance.

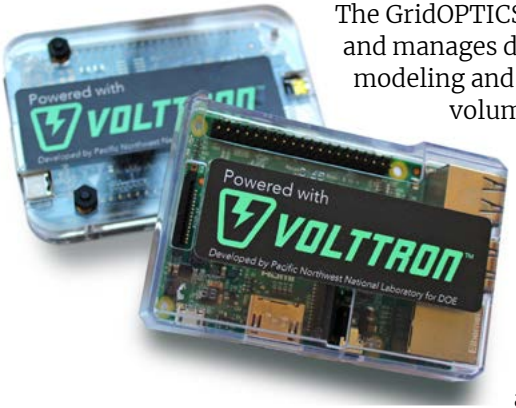
Transmission Planning Analysis Tool | 30779

Integrates analyses to reveal potential issues

This software tool integrates and presents analyses to help power system planning engineers and transmission operators make effective decisions. First, it combines the results of multiple traditional grid-planning analyses from well-known software programs. Then, it arranges those results in a systematic way that is useful for decision-making. The tool combines results from analyses of AC contingency, voltage stability, and reactive power, under multiple scenarios, to identify weak points and voltage issues that could arise in regional interconnected power systems. This tool is especially valuable for electric grid planning and operation in developing areas, where planners may have less experience with traditional planning tools.

GridOPTICS™ Grid Analysis Tool Suite | 30384

Supports grid modeling and operations



The GridOPTICS™ tool suite securely collects and manages data in real time, uses data to drive modeling and simulation, and converts large volumes of data to actionable information. The four tools in the suite can be used separately or together: 1) GridPACK™ uses advanced computing to accelerate grid modeling and simulation; 2) VOLTTRON™ enables researchers to build applications to manage energy use efficiently among appliances and devices; 3) the GridOPTICS™ Software System facilitates data collection, management, and communication among grid tools; and 4) the Framework for Network Co-Simulation merges data simulators with distribution and transmission simulators for designing more effective smart-grid tools.

DEMAND RESPONSE AND MICROGRIDS

Autonomous, Frequency-Based Demand Response

Offers high-speed, real-time load shedding to avoid widespread outages

PNNL has a large portfolio of patents covering its widely demonstrated demand response system. This system is autonomous (no communications equipment costs or delays), high-speed, and based on real-time frequency changes on the grid. It can be used to detect large system anomalies and immediately shed load to avoid widespread outages. It also can be used to modulate certain loads (e.g., water heaters and electric vehicle chargers) on a real-time basis to provide regulation services, load following, and other ancillary services. This demand response system is ideally suited to microgrids and grid resiliency applications.

Priority-Based Threshold Allocation for Frequency Response | 30797, 30854, 31275

Enhances frequency control in resilient grids

This software-based, hierarchical, distributed control architecture quickly and cost effectively prioritizes resource allocation for different appliances, both commercial and residential. The prioritization process uses a scoring methodology based on availability and performance. This process can be set by the user or be based on software calculations. The smart load coordination architecture, which can integrate millions of controllable devices into the grid, provides a faster, cleaner, and less-expensive alternative to traditional frequency response mechanisms.

Slider Setting to Select Between Microgrid Resiliency and Efficiency | 31348

Factors in emergency operations quickly and easily

This slider setting for microgrid operations allows a user to select between "more efficient" and "more resilient." Under the more efficient setting, generator dispatch and droop values adjust to increase system operating efficiency while still meeting the current load. Under the more resilient setting, the values adjust to minimize the frequency deviation from an expected increase in load or loss of generation. The value of the slider setting can be set as part of a more complex control system. The result is a single slider setting that can determine multiple set points on multiple generators for optimal operations.

Virtual Battery Assessment Tool | 31165

Determines optimal placement of demand response assets to replace grid-scale battery storage

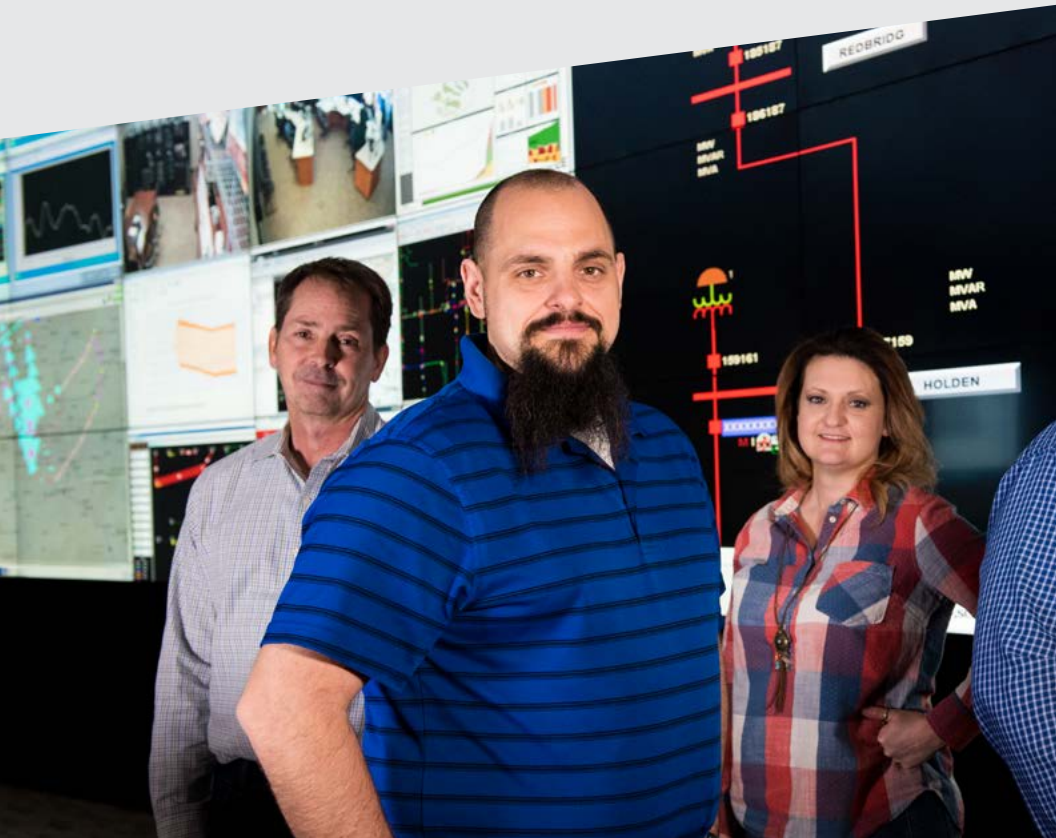
This planning and assessment tool determines where demand response assets should be deployed to achieve a value that would otherwise be provided by grid-scale battery storage. That value depends on utility goals, such as spinning reserve, regulation service, and demand deferment. The tool models building loads down to the residential level by county for each state and returns a graph showing how much capacity or energy can be delivered or absorbed over any time period. The process enables demand response to be operated like an energy storage device or virtual battery for optimal operations.

WORKING WITH US

These innovative software tools are generally available through open-source platforms, no-fee licenses, or fee-based commercial licenses. We also offer a low-cost, six-month exploratory research and option agreement to "test-drive" these technologies.

Here at PNNL, we can collaborate with you to customize these tools for your systems and needs. We can test, demonstrate, and integrate technologies at your site or ours.

A specialized facility—the Electricity Infrastructure Operations Center—is available on the PNNL campus in Richland, Washington. It integrates industry hardware and software, real-time grid data, and advanced computation in three functional control rooms with a dedicated server farm. This facility is available via physical and remote access to utilities, vendors, government agencies, and universities for development, integration, verification/validation, testing, and training.



ABOUT PNNL

Interdisciplinary teams at Pacific Northwest National Laboratory address many of America's most pressing issues in energy, the environment, and national security through advances in basic and applied science. Founded in 1965, PNNL employs more than 4,000 staff and has an annual budget of nearly $1 billion. PNNL is managed by Battelle for the U.S. Department of Energy's Office of Science.

PNNL is a recognized leader in electricity infrastructure, transactive controls, cybersecurity, and buildings research. We collaborate with industry, utilities, universities, and government to improve the resilience, reliability, and security of the nation's electricity delivery system. You can view all of our innovations available for commercialization at availabletechnologies.pnnl.gov.

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